Proceedings of Selected Papers and Abstracts of The Third International Students' Scientific Conference

"MULTIDISCIPLINARY APPROACH TO CONTEMPORARY RESEARCH - Cultural and Industrial Heritage"

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PREFACE

The Proceedings includes the selected Papers and Abstracts presented at The Third International Student Scientific Conference "Multidisciplinary Approach to Contemporary Research". The Conference was held from 21st to 22nd December 2019 at the Faculty of Agriculture, University of Belgrade, Nemanjina 6, Zemun, Belgrade. It was organized by Central Institute for Conservation, Belgrade, Scientific Association for the Development and Promotion of New Technologies, Belgrade and Faculty of Agriculture, University of Belgrade.
As in previous years, the goal and main idea of the conference were students to participate in writing of scientific papers so that they can connect science and industry in the future. Also, students who wish to pursue a scientific degree in the future had the opportunity to practice all skills and gain experience. It is for this reason, that only students were entitled to participate at the conference, who with the obligatory assistance and monitoring of teachers and/or colleagues, wrote and prepared papers and presentations.
Therefore, the Conference brought together students from various fields. Papers presented a multidisciplinary field of view and connection between different and various sciences, where all participants, could observe contemporary problems and solutions as well as trends in particular scientific disciplines.
The aim of this Conference was, also, to provide a Forum for students and researchers from various countries to exchange their ideas and achieved results.
The Conference brought together the participants from Universities, Innovation Centers, Institutes and enterprises from different countries: Serbia, Croatia, Sweden, Macedonia, Ukraine, Russia, Spain, Canada, Bosnia and Herzegovina, Greece and others.
Unlike the previous years, the conference subtitle was "Cultural and Industrial Heritage", to which a group of papers was dedicated, with the idea of reminding young people of the importance of preserving and studying objects of historical value.

The first day of the Conference was held at the Faculty of Agriculture, University of Belgrade, where the participants orally presented their papers. The second day was devoted to poster presentation and discussion about papers at the premises of Scientific Association for the Development and Promotion of New Technologies, Belgrade.
All papers have been reviewed. Considering that this was the Students Conference and the age and experience of the first authors, the reviewers *have neglected both* language and textual mistakes which have not provoked the ambiguity of the papers.
We would like to thank all authors who have contributed to this Proceedings and also to the Scientific Committee, Organizing Committee, reviewers, speakers, chairpersons, and all the conference participants for their support for delivering a successful scientific meeting.

Editors

CENTRAL INSTITUTE FOR CONSERVATION, BELGRADE
SCIENTIFIC ASSOTIATION FOR THE DEVELOPMENT AND AFFIRMATION OF NEW TECHNOLOGIES

FROM GEOMETRIC IDEA TO THE DESIGN CREATION

OD GEOMETRIJSKE IDEJE DO KREACIJE

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Abstract: *The main inspiration for all designers often comes from geometric shapes. Hence, the same idea may be the base for the creation of some architectural object, art piece, jewelry or industrial product. This paper presents several design "products" and architectural shapes which share the same geometric idea.*
Keywords: *Icosahedron, dodecahedron, design, architecture, 3d modeling and visualization, geometry*

1. INTRODUCTION

One of the most famous Greek philosopher and geometrician, Plato (427-347 BC) introduced the theory claiming that in the process of creation of "geometric structure of the universe" regular polyhedrons have had the key role. Plato associated polyhedron shapes with four main elements of nature: cube – earth, tetrahedron – fire, icosahedron - water and dodecahedron - structure of Cosmos. The origins of polyhedrons are dated back to 2000 BC due to the collection of stones from Scotland [1], that are now artefacts at the Ashmolean museum in Oxford. (Fig. 1)

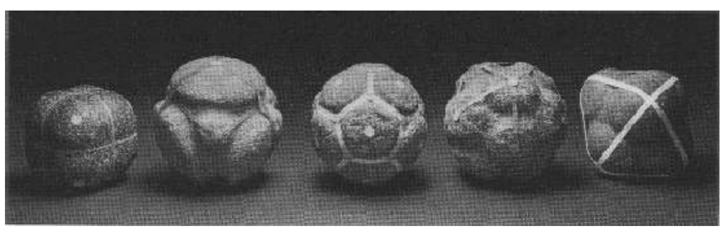

Figure 1: Stone models of the cube, tetrahedron, dodecahedron, icosahedron and octahedron - Ashmolean museum, Oxford [1]

This paper gives a close look-up to the two of well-known mathematic/geometric entities – Plato's solids, specifically among five of them, icosahedron and dodecahedron, highlighting them from several point of views: their mathematic - geometric characteristics (descriptive geometry point of view), 3D modeling (making physical models and computer modeling) and their application in art, design and architecture, as well as their original appearance in nature.

Geometrically speaking Plato's solids are polyhedrons composed of geometric shapes with equal sides, i.e. regular polygons: triangle, square and pentagon. All of the solids share geometric characteristics like symmetry, duality and static, which are very important for their application in physical world. Some of them appear in nature in the forms of crystals, hence addressing them to the divinity of nature creation. Among five Plato's solids authors of the paper choose to analyze here two polyhedrons: pentagonal dodecahedron and icosahedron.

2. MATERIALS AND METHODS

As previously stated, several scientific methods are applied in the analysis of the two chosen solids, that include:

- mathematic characteristics
- geometric constructions (descriptive geometry methods)
- computer models (computer modelling in AutoCAD software)
- application (Internet sources of images that present the applications of solids in practice).

2.1 Geometric characteristics of icosahedron and dodecahedron

The specific geometric characteristic of the two polyhedrons is that vertices of one polyhedron correspond to the faces of the other, which means that those solids are duals to each other. Namely, the center points of circumscribed circles of icosahedron's triangular faces are vertexes of inscribed dodecahedron (Fig. 2a), while center points of circumscribed circles of dodecahedron's pentagonal faces are vertexes of inscribed icosahedron (Fig. 2b).

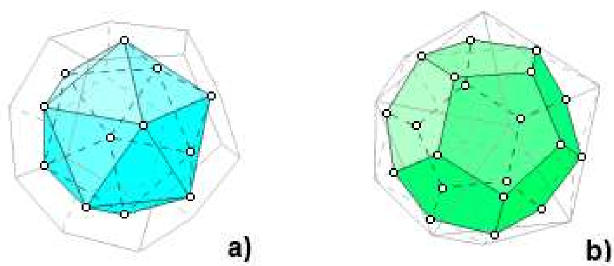

Figure 2: Duality, characteristic of icosahedron (a) and dodecahedron (b)[6]

The name icosahedron comes from words *icos* - Greek word for "twenty" and *hedron* - Indo-European word for "seat", while name dodecahedron origins are from the Greek word *dodeca*- meaning "twelve". Regular icosahedron has 12 polyhedron vertices, 30 edges and 20 equivalent equilateral triangular faces. Regular dodecahedron, is a solid composed of 20 vertices, 30 edges and 12 pentagonal faces.

The creation of a physical 3D models, obtained from piece of paper (Figs. 3a-b and 4a-b) is rather simple, in order to visualize the spatial shapes. However specific geometric knowledge is needed for understanding of spatial relations of the triangles/pentagons in spatial setting of these solids.

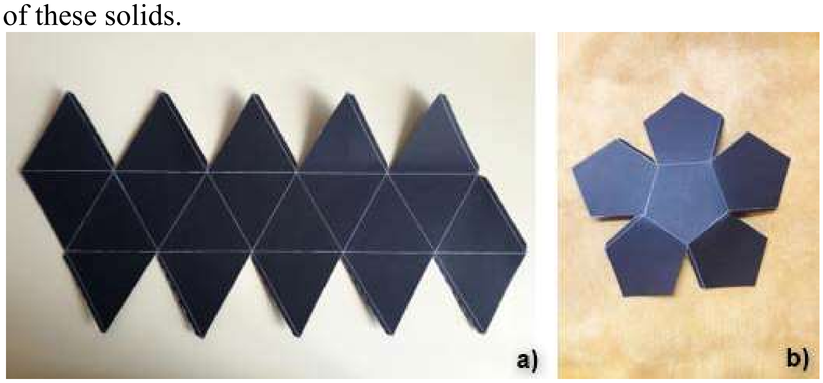

Figure 3: Nets of icosahedron (a) and half of dodecahedron (b)

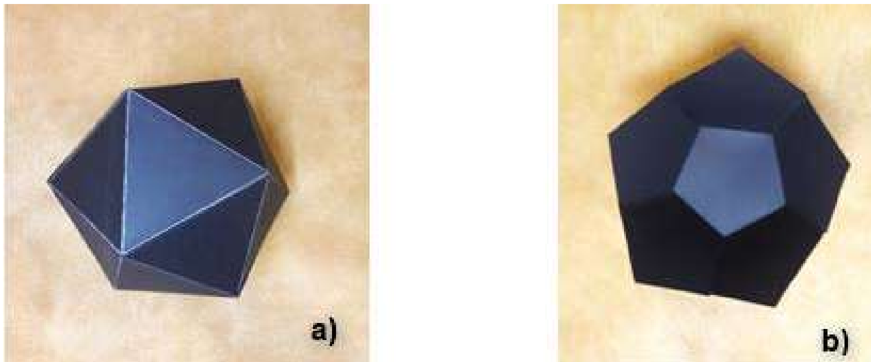

Figure 4: Paper models of icosahedron (a) and dodecahedron (b)

Descriptive geometry, in its classical approach (manual drawings), recognizes and solves this relations through specific views (top views and auxiliary views) as well as geometric constructions [2]. Auxiliary view, enables determination of heights for two "rows" of vertexes for both solids (Figs. 5a-b). The similar kind of knowledge is needed when modeling these solids in computer modelling software. The operations of 3D rotation in their 3D modelling procedures is of specific interest [3].

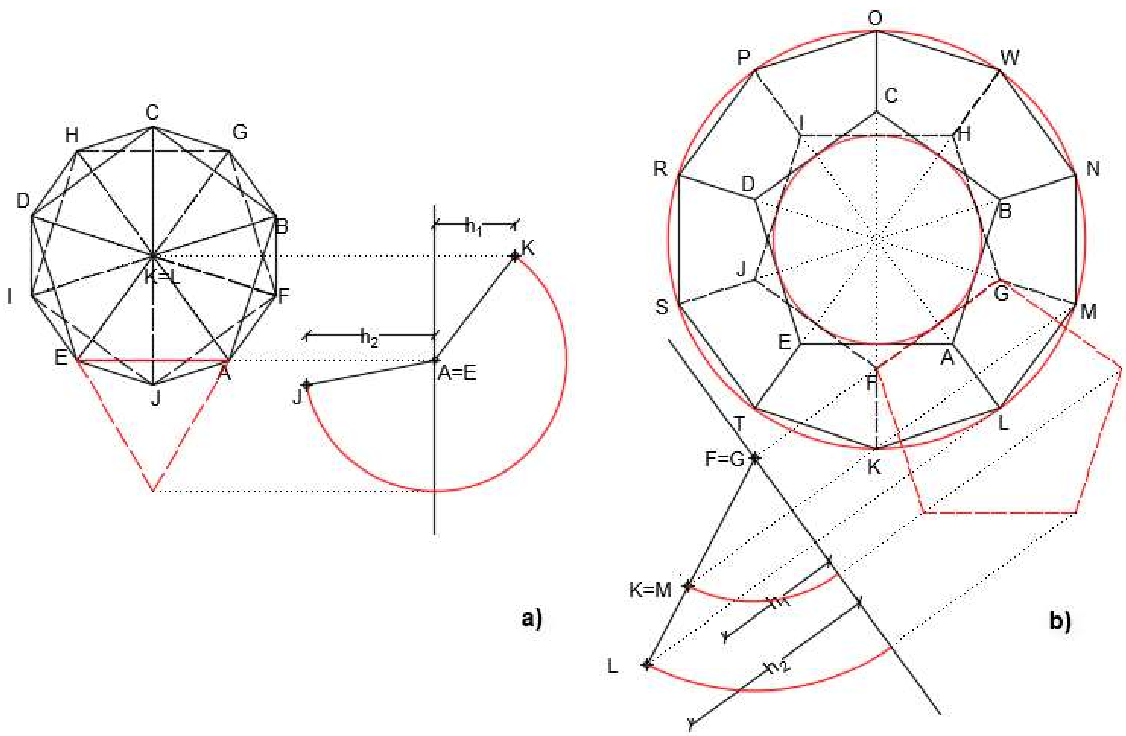

Figure 5: Geometric constructions (top view): of icosahedron (a) and dodecahedron (b)

2.2 Computer modeling of dodecahedron and icosahedron

Beside the fact that there are several mathematical software (based on programming) that create representations of solids, geometric modelling process (drawing from scratch) gives deeper insight into geometric properties and complexity of the two chosen Platonic solids, as well as some modelling operation options (instead of simple entering commands in some modelling software). The two solids: icosahedron and dodecahedron were created in AutoCAD software and the discussion is given.

The construction of ICOSAHEDRON starts with drawing of the two equal pentagons ***ABCDE*** and ***A'B'C'D'*** (the basic one is rotated for the angle of 36º). Equilateral triangle ***DEG*** is drown in real size of the icosahedron's side, docked to the side of a pentagon. In the vertical plane passing through the center of the basic pentagon, rotation of the vertex **G^o^** is performed in order to obtain spatial position of the vertex ***G*** – top of the upper pentagonal pyramid as well as the position of the lower pentagon ***A'B'C'D'E'***, i.e. vertex ***E*** (Fig. 6a). Hence the two pyramidal parts of the icosahedron are created (Fig.6b).This type of construction is the same as for octahedron [3].

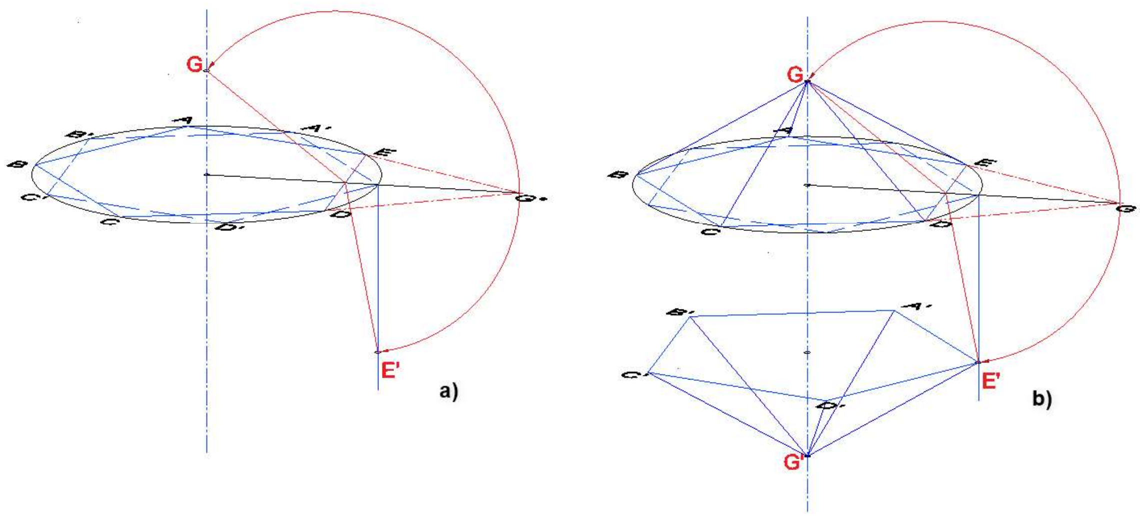

Figure 6: Construction of the heights of icosahedron

Although the tool for creation of the antiprism – mid part of the icosahedron, in the software exists, authors gave here some other geometric solution, by creating two truncated pyramids over the base of bigger pentagon, circumscribed around A'B'C'D'E' base (Fig. 7a). Initial truncated pyramid is turned up-side-down (Fig. 7b), and finally, by intersecting each other (Boolean operation), two truncated pyramid obtained pentagonal antiprism (Fig. 7c).

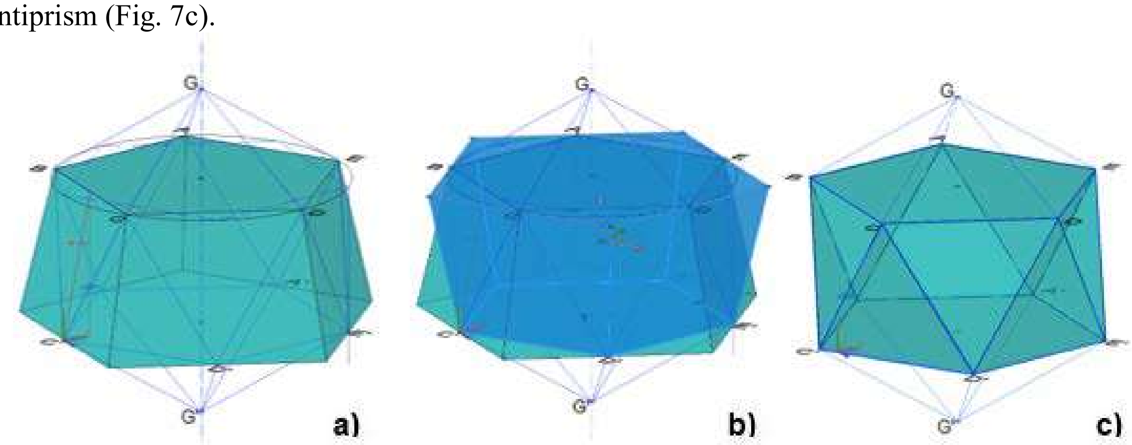

Figure 7a-c: Modeling of the two truncated pyramids, and final antiprism

Final solid model is obtained by joining (union) the two pyramidal parts and mid-antiprism (Fig.8).

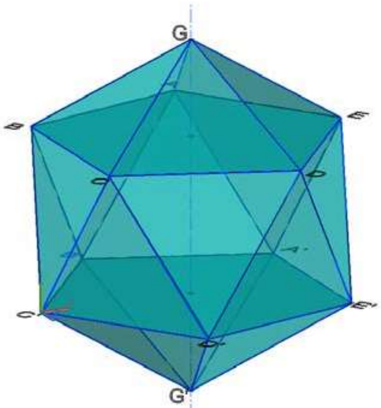

Figure 8: Final solid model of icosahedron

Modeling of DODECAHEDRON needed drawing of orthogonal projection (top view) of dodecahedron: basic pentagon (in real size) circumscribed around circle *k* (radius *r*) and five pentagons attached to its five edges, which vertexes lay on the circle k_1 (radius *2r*). The same procedure of rotating a regular pentagon docked to the edge DE, defined the position of a lower vertex G – top point of pentagonal "petal" (Fig. 9a). 3D array of "petals"-five inside fill angle of 360° gave upper part of dodecahedron (Fg.9b).

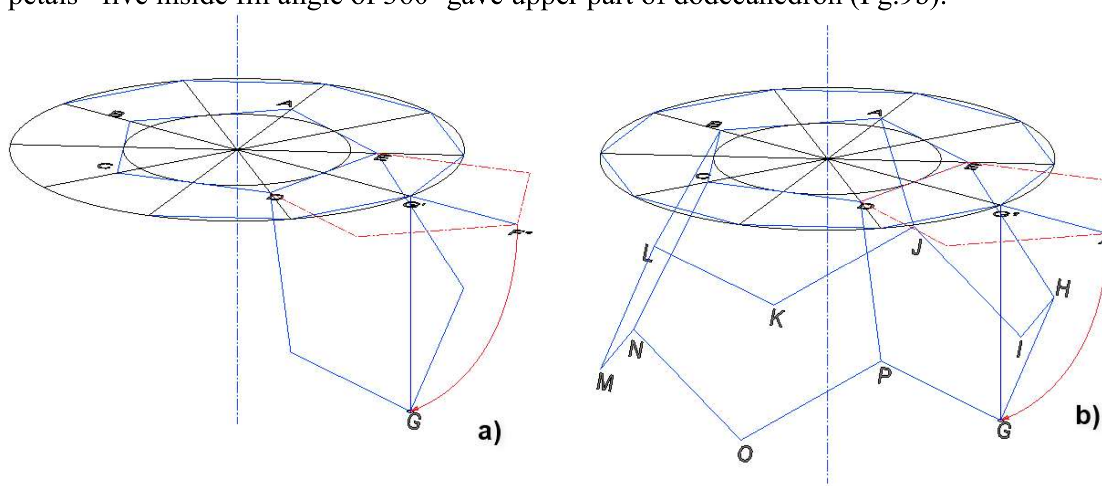

Figure 9: Wireframe modeling of the upper part of dodecahedron

3D mirroring the of the upper part of dodecahedron with respect to the base plane (Fig. 10a) and final rotation for 36° enabled moving and fitting the two (equal) parts of dodecahedron's wireframe model into integral one (Fig. 10b).

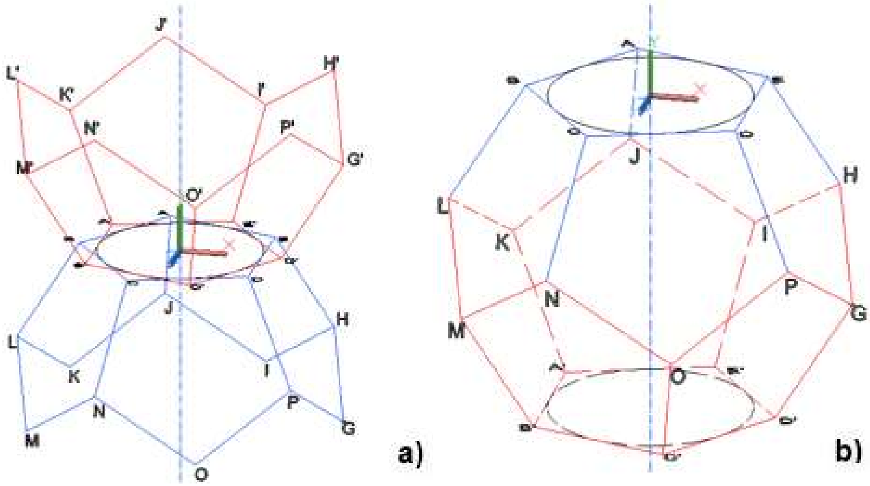

Figure 10: Mirroring and rotation of half dodecahedron (a); final dodecahedron (b)

In addition to the wireframe model, 3D modelling of a solid body of dodecahedron is obtained by the intersection (Boolean operation) of the two pentagonal pyramids which sides coincide with lateral pentagonal sides – "petals" of dodecahedron. The edges of lateral sides of the upper wireframe half of dodecahedron are extended in one direction - to meet at the top point of the pyramid, and in the other direction – to obtain its pentagonal base coplanar with the lower basic pentagonal side of dodecahedron (Fig. 11a). The same procedure follows for the corresponding (up-side-down) pyramid (Fig. 11b).

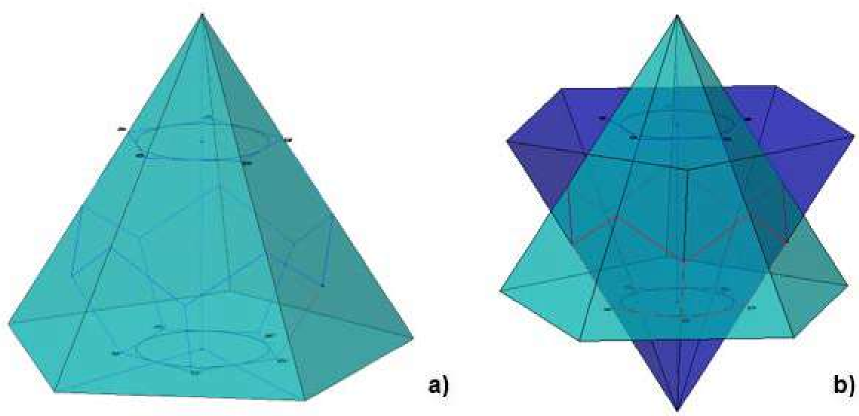

Figure 11: Modelling a pentagonal pyramid (a); the two corresponding pyramids (b)

Due to the Boolean operation – "intersect", provided for the two pyramids, final solid model of dodecahedron is obtained (Fig.12). Throughout the modeling procedure one has the opportunity to visualize the solid, manipulate with it and certainly better understand spatial relations of its parts (pentagonal sides, the heights of vertexes, inclination angles, etc.) [4].

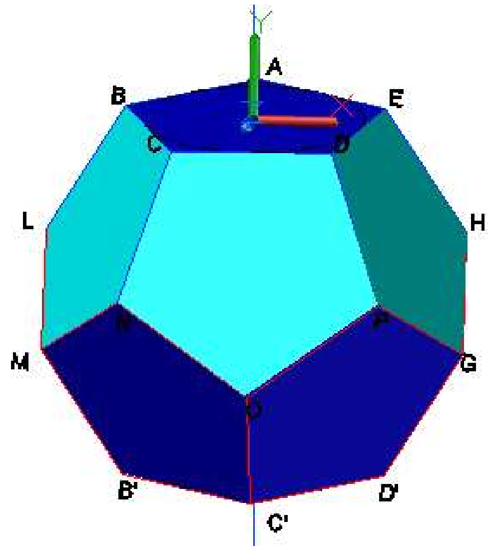

Figure 12: Final solid model of dodecahedron

2.3 The application of dodecahedron and icosahedron in arts, design and architecture

Pentagonal dodecahedron and icosahedron, due to their interesting spatial shapes, especially in modern design, inspired artists and designers to create wide range of extraordinary pieces of jewelry (Figs. 13a-c) [7-9], or decorative elements of interior design (Figs. 14a-c) [10-12]. Various design techniques and combinations of materials (plastics, glass, metal, etc.) and colors are countless.

Figure 13: Juwelry ideas inspired by icosahedron [7],[8], dodecahedron and octahedron [9]

Figure 14: Design ideas of lamps inspired by dodecahedron and icosahedron [10-12]

Architecture and geometry are firmly connected and architecture without geometry cannot exist. Due to the development of construction technologies, and extraordinary static characteristics of the analyzed shapes, the possibilities of application of polyhedral geometry in architecture are enlarged. The architects challenged themselves in various projects, some of them very creative and futuristic. Such ideas appear in the form of single units (Fig. 15a) [13] or complexes composed by combining multiple units (Fig. 15b) [14], aimed for habitation. The design of the buildings inspired by the shape of pentagonal dodecahedron certainly introduced some new aesthetics and functionality in architecture [5].

Figure 15: The application of dodecahedron shape in architectural design: single unit – futuristic housing (a) [13], complex structure – habitation complex built in Jerusalem (b) [14]

2.3 The appearance of dodecahedron and icosahedron in nature

The nature itself gives several examples of minerals' crystals in the shapes of dodecahedron and icosahedron (Fig.16a-c). Minerals shaped as icosahedron or dodecahedron belong to the type of isometric system of cristalization. Pyrite (FeS_2) is a mineral that cristalyze in meny forms: iron pyrite shape is of icosahedron; pyritohedron (dodecahedron). Cobaltite cristalyzes as icosahedron, etc. [15-17].

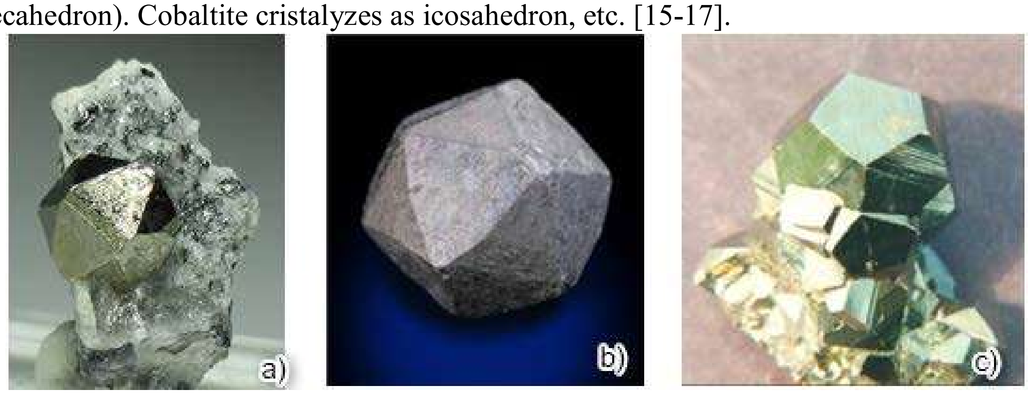

Figure 16: Icosahedron and dodecahedron shapes of minerals' crystals: iron pyrite -icosahedron (a)[15], cobaltite - icosahedron (b)[16], pyritohedron (c)[17]

4. CONCLUSION

This research, although thematically oriented to geometry and geometric shapes of the two Platonic solids joined science and practical life. Several creative disciplines, connected to geometry: art, architecture and design, by the inspiration of the designers overlap in the basic need of geometric knowledge i.e. geometric characteristics of icosahedron and dodecahedron, and their geometric constructions.

Authors of the paper shown the origins of the two solids, introduced geometric approach in their contemporary computer modeling, useful for designers of all sorts, while having in mind that the nature is probably the best spontaneous creator of this shapes. However, the conclusion is that creative inspiration never dries and joined with adequate knowledge it can create miracles in real life.

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